FOG FORECASTING FOR FIRE CONTROL IN SOUTHERN CALIFORNIA

By ARVY A. LOTHMAN

[Weather Bureau, Pasadena, Calif., September 1937]

Summer stratus or, so-called, California "high fog" plays an important role in fighting forest fires in the littoral region of southern California. If fog is expected on a going fire, men may be released, thereby reducing the cost of suppression; the fire lines may be drawn in closer to the actual fire, thereby reducing the actual acreage of burn. For these reasons it is advantageous to have reliable forecasts as to whether or not fog will occur over small local areas.

The forecasts of fog may have to be made for territory extending from the Mexican border to the Monterey-San Luis Obispo County line, for elevations from sea level to nearly 4,000 feet, extending from the coast to about 60 miles inland. Pasadena, where the practicability of fog forecasting for fire control was tested, lies at an elevation of 850 feet above sea level, about 25 miles from the coast at the base of mountains which rise to over 5,000 feet.

An explanation of the theory of formation by convection of this summer fog has been given by Petterssen.[1] The maintenance of the inversion necessary for the fog to form was shown to be due to differences in the radiative qualities of different air masses by Bowie,[2] and was later amplified by Blake [3] and Petterssen.

Explaining the processes involved in the formation of the fog, Petterssen says:

> The air which produces fog is unstable and the fog or stratus forms because of convection under the temperature inversion separating the Pacific air from the dry air aloft. Outgoing radiation from the top of the moist layer is effective in maintaining the temperature inversion and the instability of the air.

The surface air particles are forced to rise due to the instability of the air, and fog is formed if the condensation level of this air is below the base of the temperature inversion. Figure 1 shows a typical temperature-altitude curve which favors fog formation.

A practical method of using the theory outlined by Petterssen has been worked out at the Pasadena office for forecasting the extent to which the fog will form inland. The forecasts are for use in forest fire control and are made every evening. Therefore the periods covered by the fog forecasts are for that night and the following morning.

Since fog may form when the convective condensation level of the surface air particle is lower than the base of the inversion, it is first necessary to determine the height of this base which will prevail during the forecast period. Although it is admitted that a more accurate method, such as an aerographic sounding, should be used to determine the air structure just prior to making the forecast, the height of the base of the inversion can be closely estimated by various indirect methods. For example: (1) Ceilings are reported from airway stations along the coast. If fog is just forming or has just formed, reports from these sources will give an estimate as to its height. (2) Changes that have taken place in the air structure since the morning aerographic soundings were taken at San Diego and Long Beach may be estimated. Changes in wind direction in the air below the inversion are the primary reasons for changes in the height of the base of the inversion, according to Petterssen.

[1] On the Causes and the Forecasting of the California Fog, Sverre Petterssen, Journa of the Aeronautical Sciences, vol. 3, July 1936.

[2] The Summer Nighttime Clouds of the Santa Clara Valley, California, Edward H Bowie, MONTHLY WEATHER REVIEW, vol. 61, February 1933, pp. 40-41.

[3] Further Conclusions From Additional Observations in the Free Air Over San Diego California, Dean Blake, MONTHLY WEATHER REVIEW, vol. 62, June 1934: pp. 195-199.

The next consideration is the possibility of a change in the air mass, during the forecast period, which would change the air structure. This can be determined from the synoptic chart; however, in southern California during the summer very few changes of air mass take place.

Since no fog can form above the base of the inversion, out attention is directed to all the area lying below this elevation. From surface reports of temperature, relative humidity, and pressure, the mixing ratio of the air in the area is determined. On a pseudo-adiabatic chart, from the point where the saturation mixing ratio line (corresponding to the mixing ratio of the surface particle) crosses the base of the inversion, the dry adiabat is followed down to the surface elevation of the forecast area; this will then give the critical temperature, i. e., the temperature to which the surface air must be cooled before fog will form.

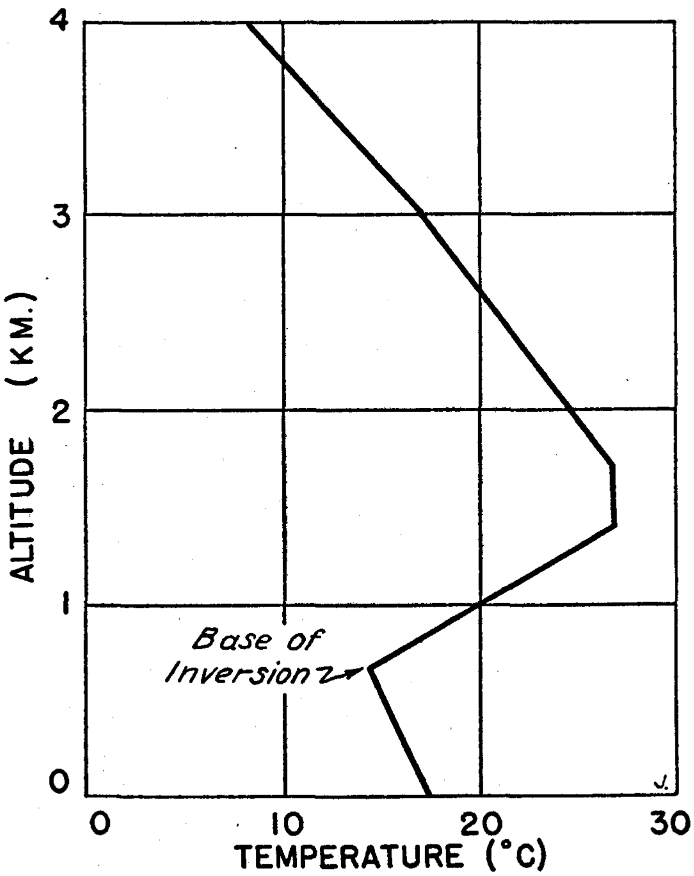

FIGURE 1.—Temperature-altitude curve, July 20, 1937, Long Beach, Calif.

The next consideration is the probable minimum temperature that will be reached during the forecast period. Fog should be predicted in all areas where the temperature is expected to fall below the critical temperature.

In using ceiling heights as reported by coast airway stations for determining the base of the inversion, it has been found that in some cases the reported ceilings are so low that they cannot be explained as due to changes in the air mass subsequent to the morning aerographic soundings taken at San Diego and Long Beach. The low base of the inversion would indicate that fog could occur only along the immediate coast at low elevations; however, as shown by Petterssen, in several cases the low ceiling was due to a double inversion that produced fog in the morning some time after insolation had destroyed the small lower inversion.

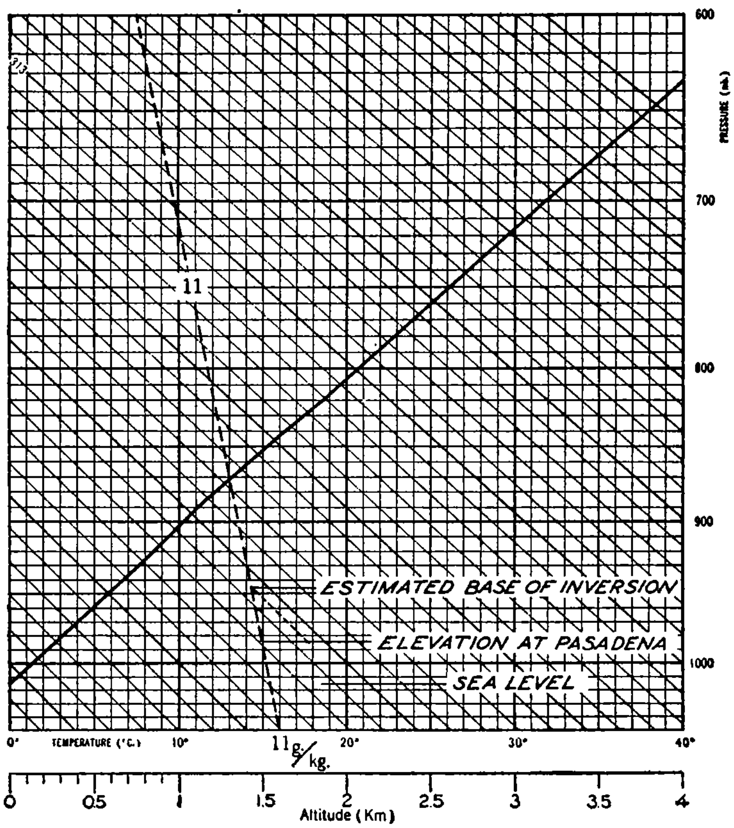

FIGURE 2.—Diagram showing method employed to calculate the temperature necessary to produce fog at Pasadena on the evening of July 18, 1937. The solid diagonal line is a pressure-height curve to be used in conjunction with the lower horizontal scale for determining altitude

An example of a double inversion at Pasadena occurred on the morning of July 19, 1937. When the forecast was made the previous evening, the base of the inversion was estimated to be about 600 meters, as determined from the morning aerographic observations. The surface-mixing ratio at Pasadena was calculated to be about 11g/kg. From an altitude of 600 meters (see figure 2) on the 11g/kg curve of mixing ratio, projecting down along the dry adiabat to the surface elevation of Pasadena a temperature of 17.8° C. was found necessary to produce fog. The minimum temperature for the next morning was expected to be several degrees lower than that; therefore fog was expected to form.

At 7:50 p. m., July 18, the airway reports indicated temperatures from 17.9° to 18.4° C. and mixing ratios of about 11g/kg on the coast. Projecting the surface sea level temperature upward along the dry adiabat to the 11 curve of constant saturation mixing ratio would indicate a convective condensation level between 300 and 350 meters. Yet no fog was reported overhead by any of the stations, which would indicate that the base of the inversion was below 300 meters. Some of the stations reported low fog banks seaward, which would also indicate the base of the inversion to be very low. Since there was no justification for such a low base for the inversion, as shown by the synoptic situation, the only conclusion to be drawn was that a double inversion existed in the air. This proved to be true because by 4:50 a. m., July 19, fog was reported all along the coast, with ceilings ranging from 150 meters to 240 meters. No fog had occurred at Pasadena or Burbank up to this time. At 6:30 a. m., 1 hour and 45 minutes after sunrise, when the lower inversion was destroyed, fog formed at Pasadena and continued until about 7:45 a. m. Burbank reported dense fog at 6:50 a. m.; and the ceiling at San Diego had risen to about 400 meters.

A plotting board was constructed to aid in making quick analyses for fog forecasting: On one side a Millar nomogram [4] is mounted under celluloid for determining the surface mixing ratio. On the other side a pseudo-adiabatic diagram was mounted to be used in determining the temperature necessary to produce fog.

The method of fog forecasting presented in this article is considered to be reliable whenever the height of the base of the inversion can be closely determined, and when a fall in temperature below that necessary to produce fog is predictable. In the short period of 4 months' trial at Pasadena it has been highly successful.

[4] Rapid Methods Of Calculating The Rossby Diagram, F. Graham Millar, Bulletin of the American Meteorological Society, October 1935, pp. 229-233.

SYNOPTIC ANALYSIS OF THE SOUTHERN CALIFORNIA FLOOD OF MARCH 2, 1938

By CHARLES H. PIERCE

[Weather Bureau, Washington, June 1938]

On the morning of March 1, a deep LOW with a wide-open warm sector was centered at latitude 34° N., about half way between San Francisco and the Hawaiian Islands.

The warm front of this LOW was peculiar because instead of extending southward, as do most warm fronts of the Pacific LOWS in this locality, it extended east-southeastward and was connected to a cold front of a preceding system which had passed inland on the previous day. This cold front extended through southern California and passed into Mexico during the day, giving California temporary clearing that afternoon.

In the meantime, the LOW which was centered at 34° N. and 140° W. was occluding and moving rapidly northeastward, being centered at approximately 39° N. and 132° W. at 4:30 p. m. (all times Pacific Standard). In spite of the rapid occlusion near the center, there was still a very extensive warm sector with a supply of moist Tropical Pacific air a short distance southwest of southern California. With the LOW moving so rapidly northeastward, it meant that the cold front that had passed southward of the international boundary would soon change its direction of motion, and start returning as a warm front.

Late that night rain was already falling along the coast from the overrunning warm air to the southwest.

At 4:41 a. m. March 2, the low center was off the Oregon coast with an occluded front, north of Marshfield and Roseburg, Oreg., which curved sharply southwestward into California. The position of the fronts and the pressure distribution over California at 4:41 a. m. is shown by the map of that time for March 2.

In the following 6 hours the cold and occluded fronts advanced rapidly eastward with the warm front moving